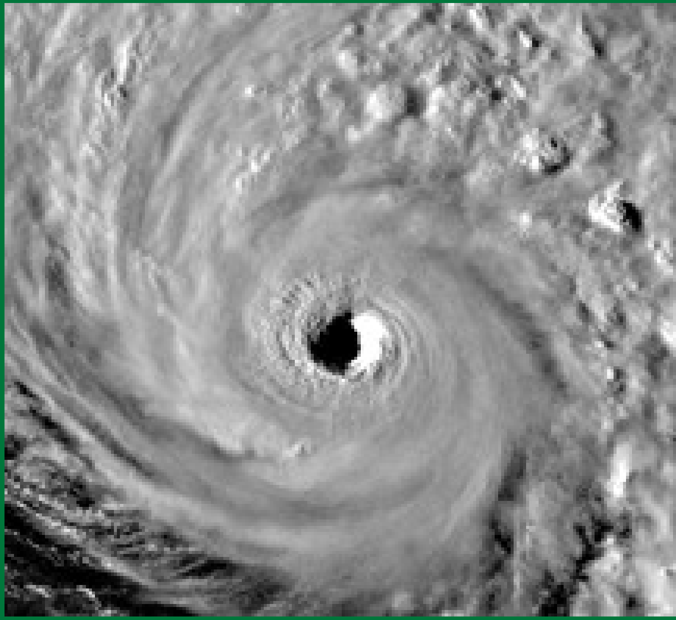
Hurricanes

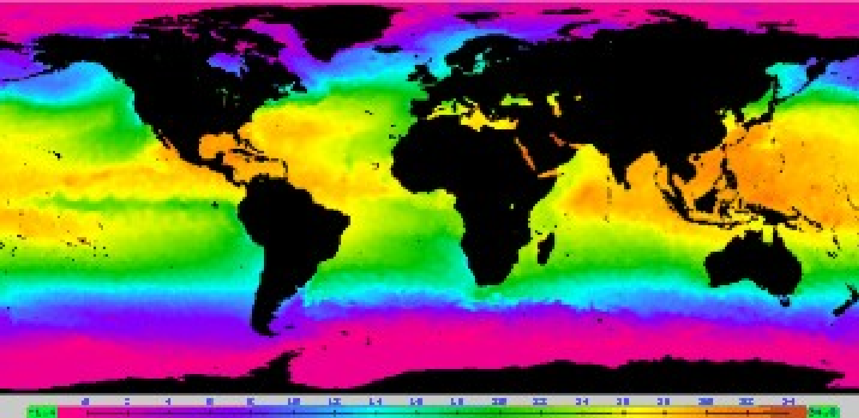
Hurricanes

a tropical cyclone with winds > 64 knots

Hurricanes are tropical cyclones with winds that exceed 64 knots (74 mi/hr) and circulate counter-clockwise about their centers in the Northern Hemisphere (clockwise in the Southern Hemisphere) .



Hurricanes are formed from simple complexes of thunderstorms. However, these thunderstorms can only grow to hurricane strength with cooperation from both the ocean and the atmosphere. First of all, the ocean water itself must be warmer than 26.5 degrees Celsius (81°F). The heat and moisture from this warm water is ultimately the source of energy for hurricanes. Hurricanes will weaken rapidly when they travel over



This is a sea surface temperature map for the northern hemisphere summer. The yellow, orange, and red colors show water temperatures warm enough to sustain hurricanes (> 26.5°C).

Related to having warm ocean water, high relative humidities in the lower and middle troposphere are also required for hurricane development. These high humidities reduce the amount of evaporation in clouds and maximizes the latent heat released because there is more precipitation. The concentration of latent heat is critical to driving the system.

The vertical wind shear in a tropical cyclone's environment is also important. Wind shear is defined as the amount of change in the wind's direction or speed with increasing altitude. The video below shows how

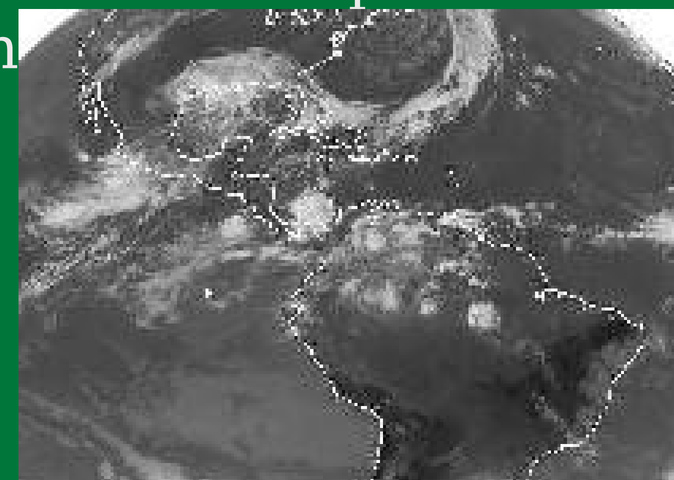
The vertical wind shear in a tropical cyclone's environment is also important. Wind shear is defined as the amount of change in the wind's direction or speed with increasing altitude. The video below shows how wind shear plays a role in hurricane formation.

When the wind shear is weak, the storms that are part of the cyclone grow vertically, and the latent heat from condensation is released into the air directly above the storm, aiding in development. When there is stronger wind shear, this means that the storms become more slanted and the latent heat release is dispersed over a

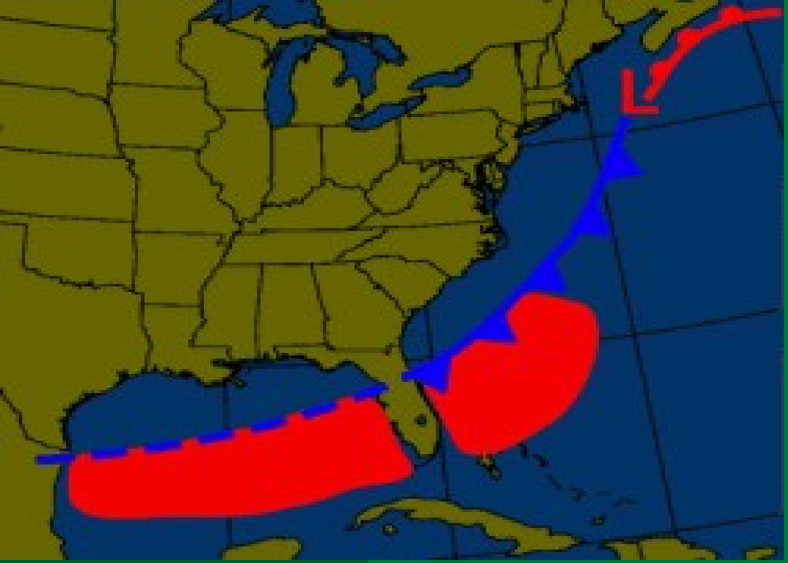
Initial Development

the storms that become hurricanes

Hurricanes initiate from an area of thunderstorms. These thunderstorms are most commonly formed in one of three different ways. The first is the InterTropical Convergence Zone (ITCZ). The ITCZ is a near-solid ring of thunderstorms surrounding the globe found in the tropics. In the diagram below, the easterly trade winds converge near the equator and ... which can be seen

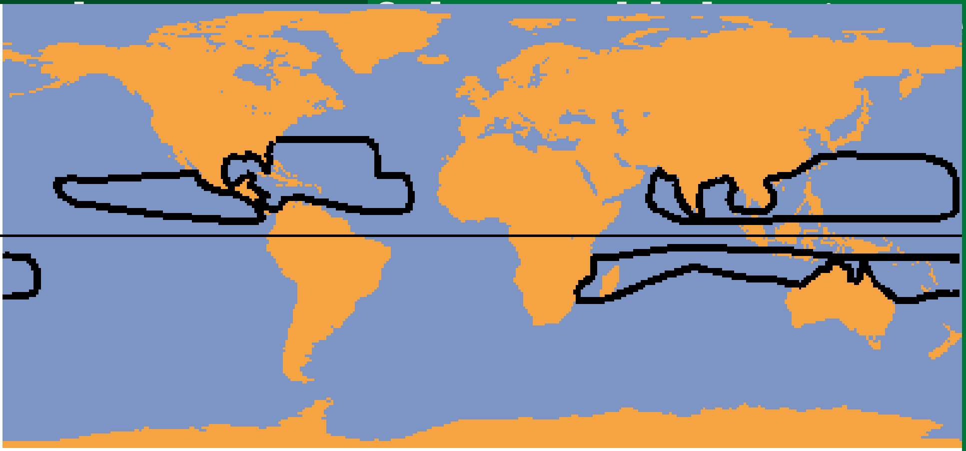


The second source for thunderstorms that can create hurricanes are from eastward moving atmospheric waves, called easterly waves. Easterly waves are similar to waves in the mid-latitudes, except they are in the easterly trade-flow. Convergence associated with these waves creates



The third mechanism is along old frontal boundaries that drift into the Gulf of Mexico or coastal Florida. The lift associated with these fronts can be enough to initiate storms, and if the atmospheric and oceanic conditions are sufficient, tropical cyclones can develop that way as well.

The map below shows the regions throughout the world where tropical cyclones originate. Tropical cyclones are more commonly found in the northern hemisphere, but the Pacific and Indian Oceans both produce hurricanes in the southern hemisphere. However, in



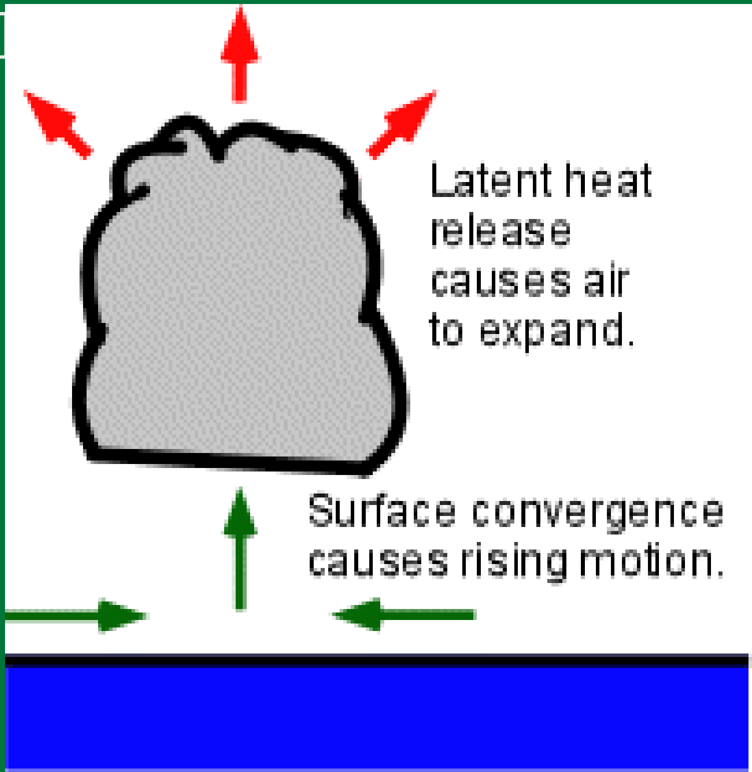
s are called by different names.

At the equator, ocean surface temperatures are warm enough to produce hurricanes, but none form. This is because there is not enough coriolis force to create spin and

CIS
K

how thunderstorms become hurricanes

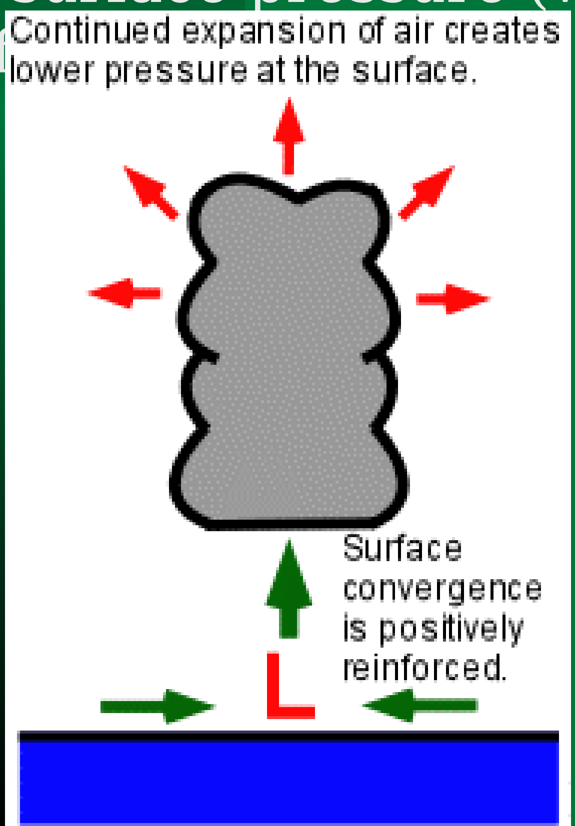
CISK, or "Convective Instability of the Second Kind", is a popular theory that explains how thunderstorms can evolve and organize into hurricanes. CISK is a positive feedback mechanism, meaning that once a process starts, it causes events which enhance the original process, and the whole cycle repeats itself over and over. Below is a video explanation of CIS



The surface air that spirals into the center of a low pressure system creates convergence (green horizontal arrows) and forces air to rise in the center (green vertical arrow). This air cools and moisture condenses which releases latent heat into the air. It is this latent heat that provides the energy to

Latent heat is simply heat released or absorbed by a substance (in this case, water vapor) as it changes its state. When water vapor condenses into liquid, it releases this heat into the surrounding atmosphere. The atmosphere around this condensation then warms.

Since warm air is less dense than cooler air, the warmer air takes up more space. This expansion of this air (red arrows) forces more air outside away from the center of the storm and the surface pressure (which is the weight of the air above the surf



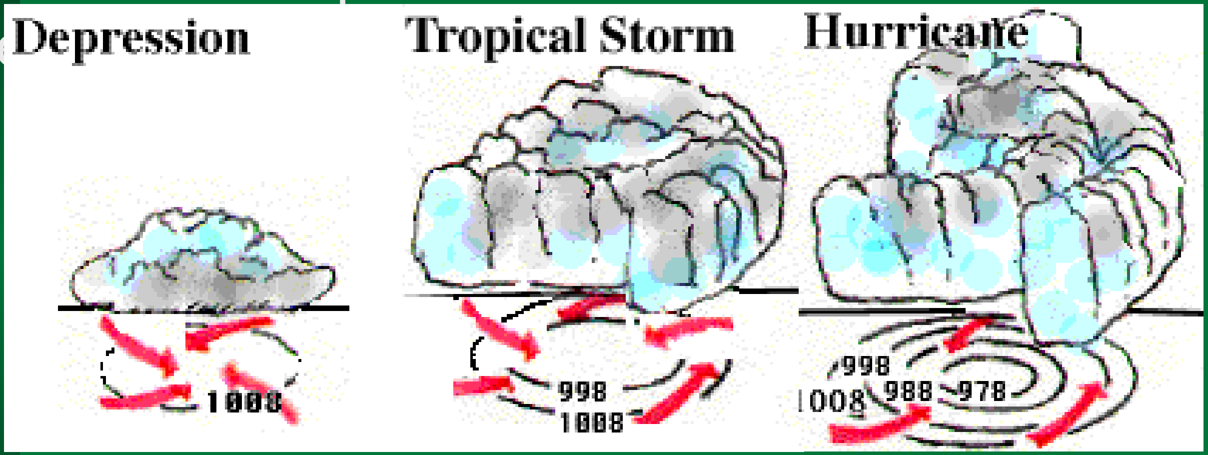
When the surface pressure decreases, a larger pressure gradient is formed, and more air converges towards the center of the storm. This creates more surface convergence and causes more warm moist surface air to rise above the surface. This air, as it cools, condenses into clouds. While it does this, it releases even more latent heat.

This cycle continuously repeats itself each time intensifying the storm until other factors, such as cool water, land, or high wind shear

Stages of Development

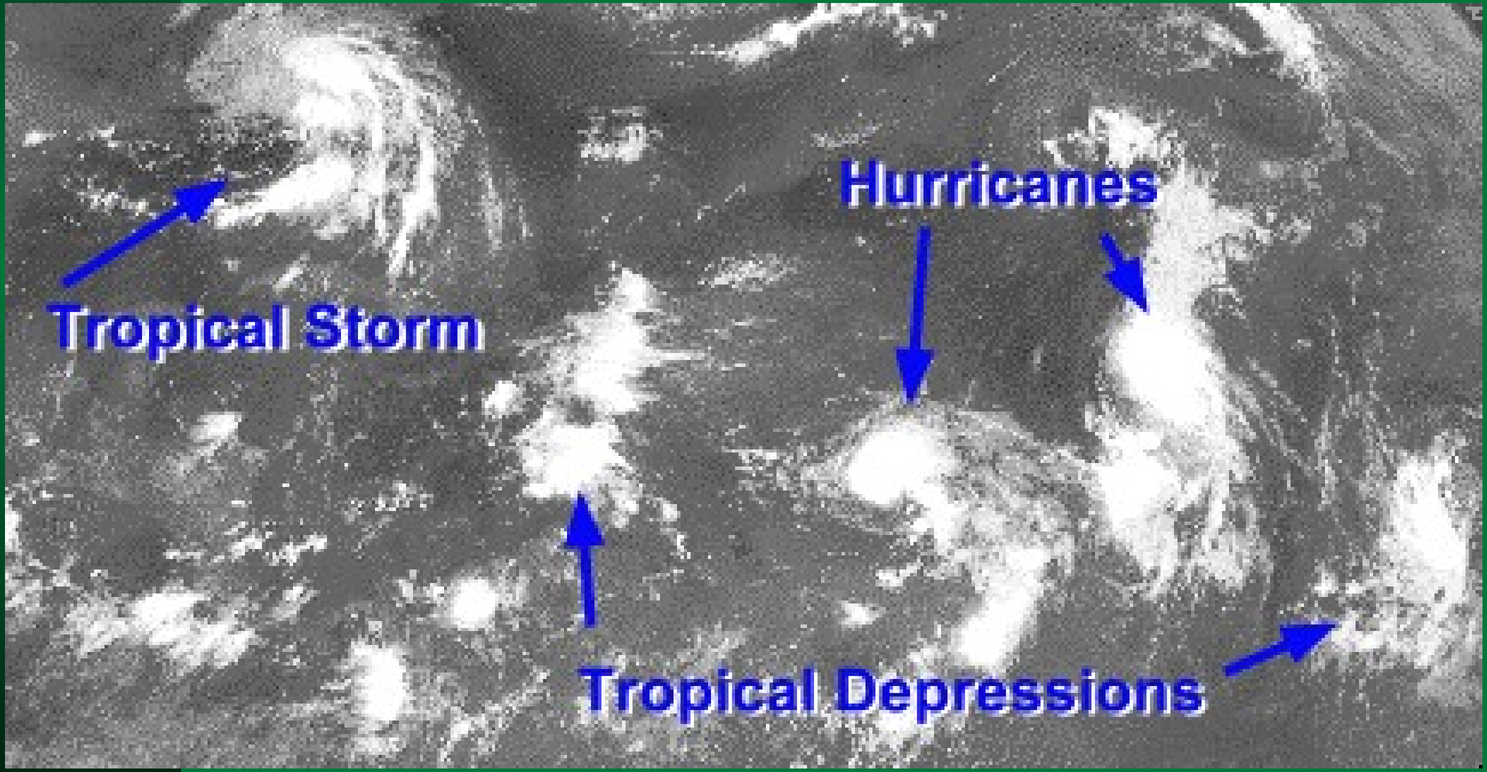
from tropical depression to hurricane

Hurricanes evolve through a life cycle of stages from birth to death. A tropical disturbance in time can grow to a more intense stage by attaining a specified sustained wind speed. The progression of tropical disturbances can be seen in the three image

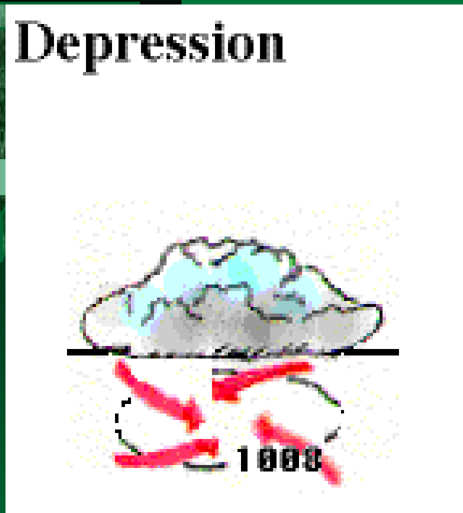


Hurricanes can often live for a long period of time -- as much as two to three weeks. They may initiate as a cluster of thunderstorms over the tropical ocean waters. Once a disturbance has become a tropical depression, the amount of time it takes to achieve the next stage, tropical storm, can take as little as half a day to as much as a couple of days. It may not happen at all. The same may occur for the amount of time a tropical storm needs to intensify into a hurricane. Atmospheric and oceanic conditions play major roles in determining

Below, in this satellite image from 1995, we can see different tropical disturbances in each stage are evident. At the far left, Tropical storm Jerry is over Florida, while Hurricanes Iris and Humberto are further east, amongst a couple of tropical depressions.



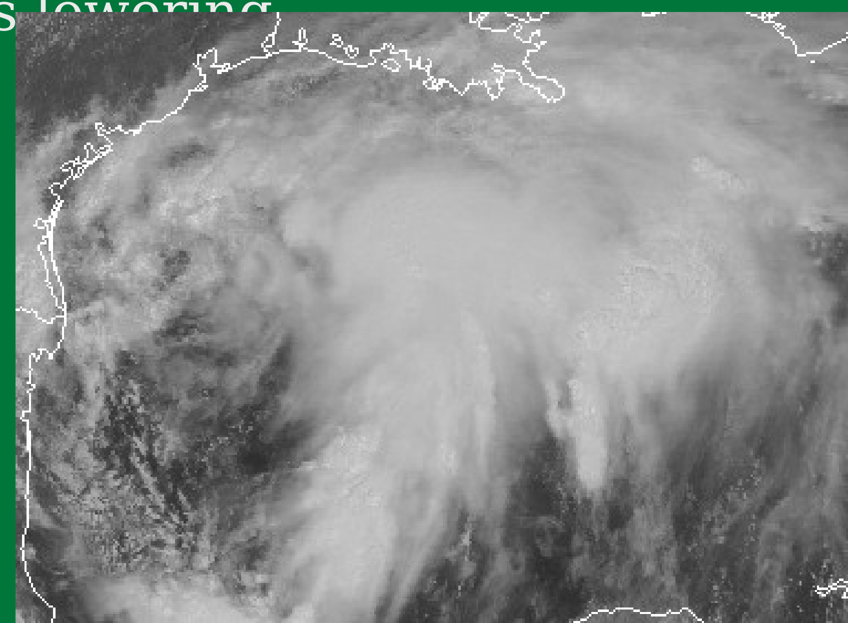
Tropical Depression

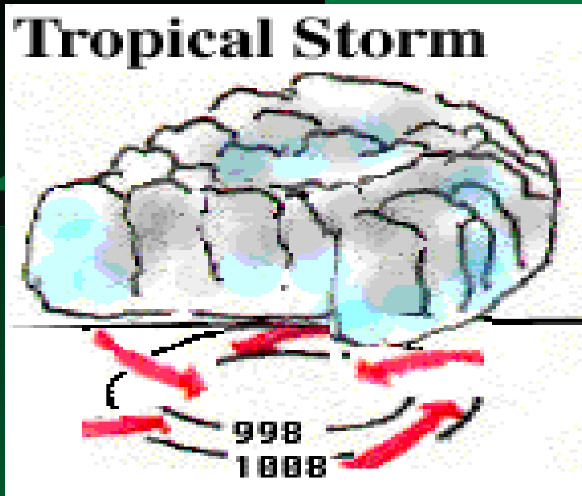


Once a group of thunderstorms has come together under the right atmospheric conditions for a long enough time, they may organize into a tropical depression. Winds near the center are constantly between 20 and 34 knots (23 - 39 mph).

A tropical depression is designated when the first appearance of a lowered pressure and organized circulation in the center of the thunderstorm complex occurs. A surface pressure chart will reveal at least one closed isobar to reflect this lowering.

When viewed from a satellite, tropical depressions appear to have little organization. However, the slightest amount of rotation can usually be perceived when looking at a series of satellite images. Instead of a round appearance similar to hurricanes, tropical depressions look like individual thunderstorms that are



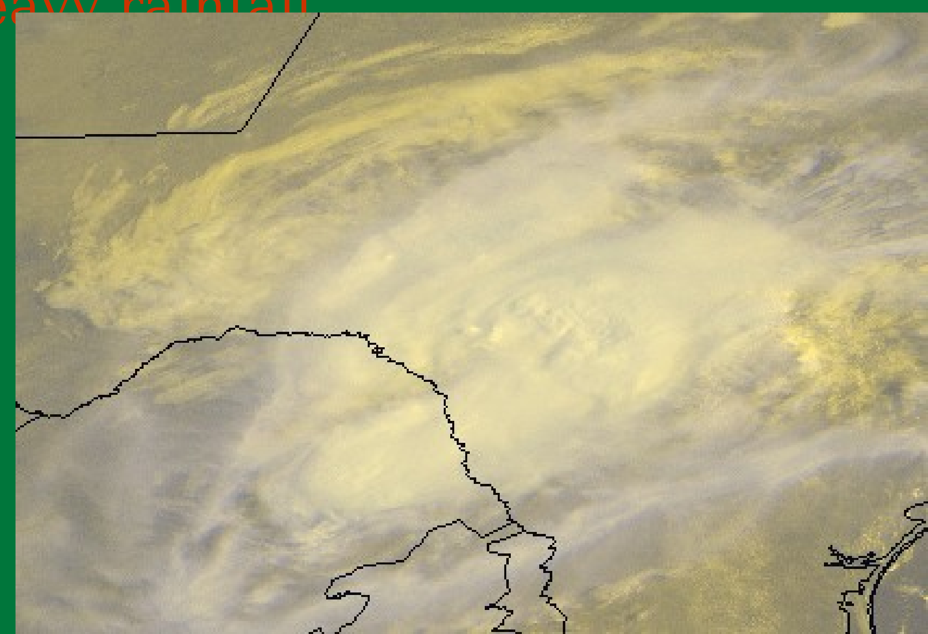


Tropical Storms

Once a tropical depression has intensified to the point where its maximum sustained winds are between 35-64 knots (39-73 mph), it becomes a tropical storm. It is at this time that it is assigned a name. During this time, the storm itself becomes more organized and begins to become more circular in shape -- resembling a hurricane.

The rotation of a tropical storm is more recognizable than for a tropical depression. Tropical storms can cause a lot of problems even without becoming a hurricane. However, most of the problems a tropical storm cause stem from heavy rainfall.

The above satellite image is of tropical storm Charlie (1998). Many cities in southern Texas reported heavy rainfall between 5-10 inches. Included in these was Del Rio, where more than 17 inches fell in just one day, forcing people from their homes and

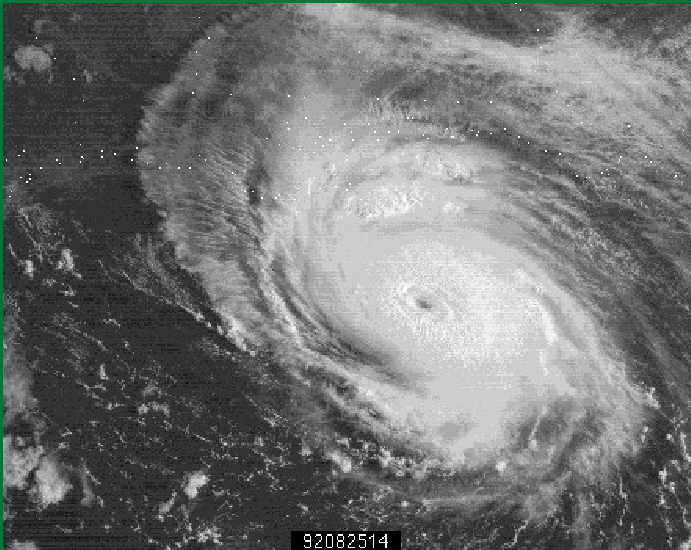


Hurricanes

As surface pressures continue to drop, a tropical storm becomes a hurricane when sustained wind speeds reach 64 knots (74 mph). A pronounced rotation develops around the central core.

Hurricanes are Earth's strongest tropical cyclones. A distinctive feature seen on many hurricanes and are unique to them is the dark spot found in the middle of the hurricane. This is called the eye. Surrounding the eye is the region of most intense winds and rainfall called the eye wall. Large bands of clouds and precipitation spiral from the eye wall and are thusly called spiral rain bands.

Hurricanes are easily spotted from the previous features as well as a pronounced rotation around the eye in satellite or radar animations. Hurricanes are also rated according to their wind speed on the Saffir -Simpson scale. This scale ranges from categories 1 to 5, with 5 being the most devastating. Under the right atmospheric conditions, hurricanes can sustain



The Eye

the center of the storm

The most recognizable feature found within a hurricane is the eye. They are found at the center and are between 20-50km in diameter. The eye is the focus of the hurricane, the point about which the rest of the storm rotates and where the lowest surface pressures are found in the storm. The image below is of a hurricane (called cyclone in the Southern Hemisphere). Note the e

Skies are often clear above the eye and winds are relatively light. It is actually the calmest section of any hurricane.

The eye is so calm because the now strong surface winds that converge towards the center never reach it. The coriolis force deflects the wind slightly away from the center, causing the wind to rotate around the center of the hurricane (the eye wall), leaving the exact center (the eye) calm.

An eye becomes visible when some of the rising air in the eye wall is forced towards the center of the storm instead of outward -- where most of it goes. This air is coming inward towards the center from all directions. This convergence causes the air to actually sink in the eye. This sinking creates a warmer environment and the clouds evaporate leaving a clear area in the center.

The Eye Wall

a hurricane's most devastating region

Located just outside of the eye is the eye wall. This is the location within a hurricane where the most damaging winds and intense rainfall is found. The image below is of a hurricane (called cyclone in th

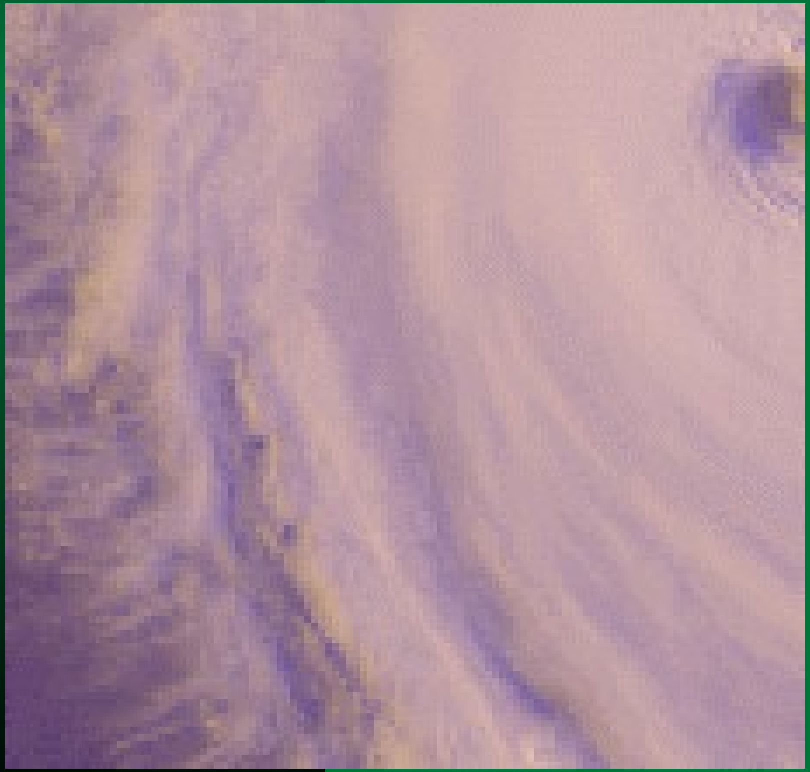
Eye walls are called as such because oftentimes the eye is surrounded by a vertical wall of clouds. The eye wall can be seen in the picture above as the thick ring surrounding the eye.

At the surface, the winds are rushing towards the center of a hurricane -- forcing air upwards at the center. The coriolis force acts on these surface winds, and in the Northern Hemisphere, the deflection is to the right. The convergence at the eye wall is so strong here that the air is being lifted faster and with more force here than any other location of the hurricane. Thus, the moisture

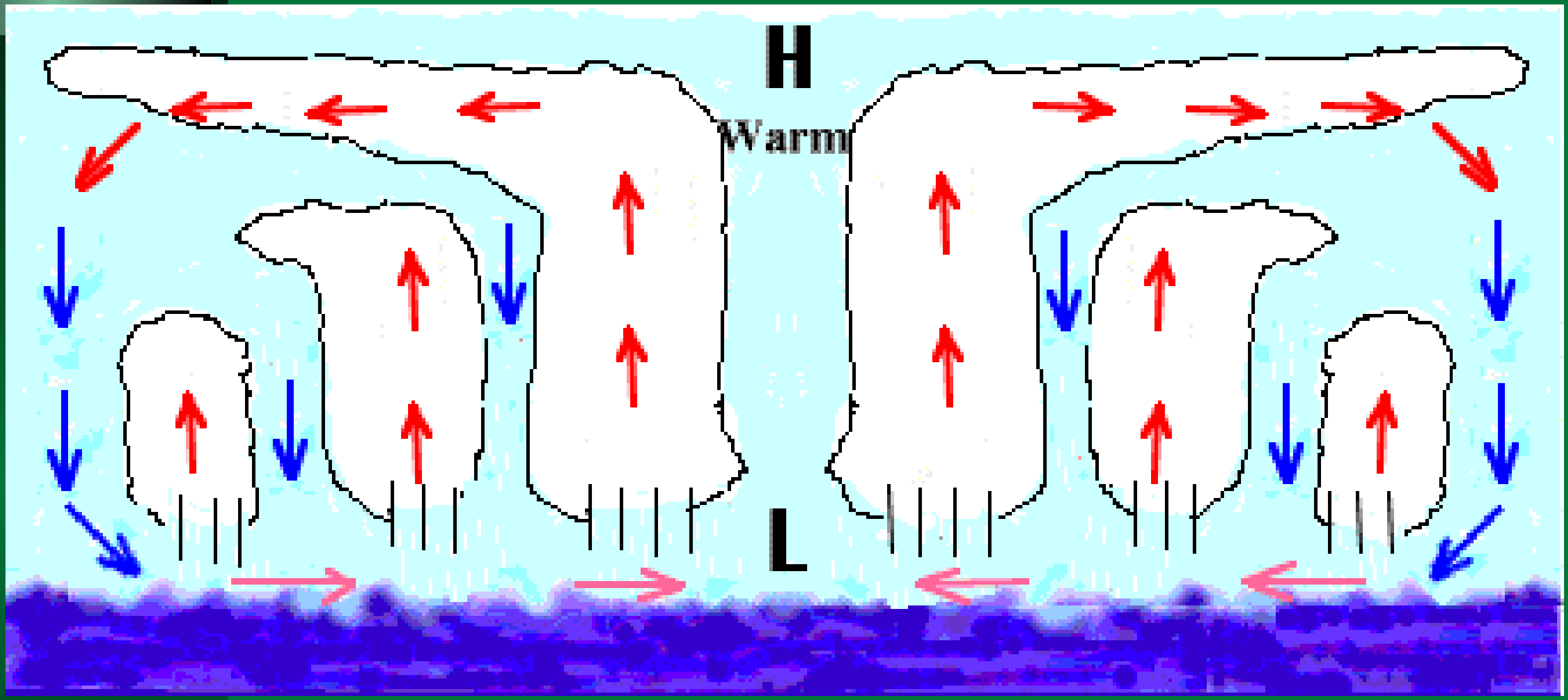
Spiral Bands

where more rain is found

Radiating outward from the eye wall one can see a banded structure within the clouds. These clouds are called either spiral rain bands (or spiral bands). The image below is of a hurricane (called cyclone in the Southern Hemisphere).



There are sometimes gaps in between these bands where no rain is found. In fact, if one were to travel between the outer edge of the hurricane to its center, one would normally progress from light rain to dry back to slightly more intense rain again over and over with each period of rainfall being more intense and lasting longer until reaching the eye. Upon exiting the eye and moving towards the edge of the

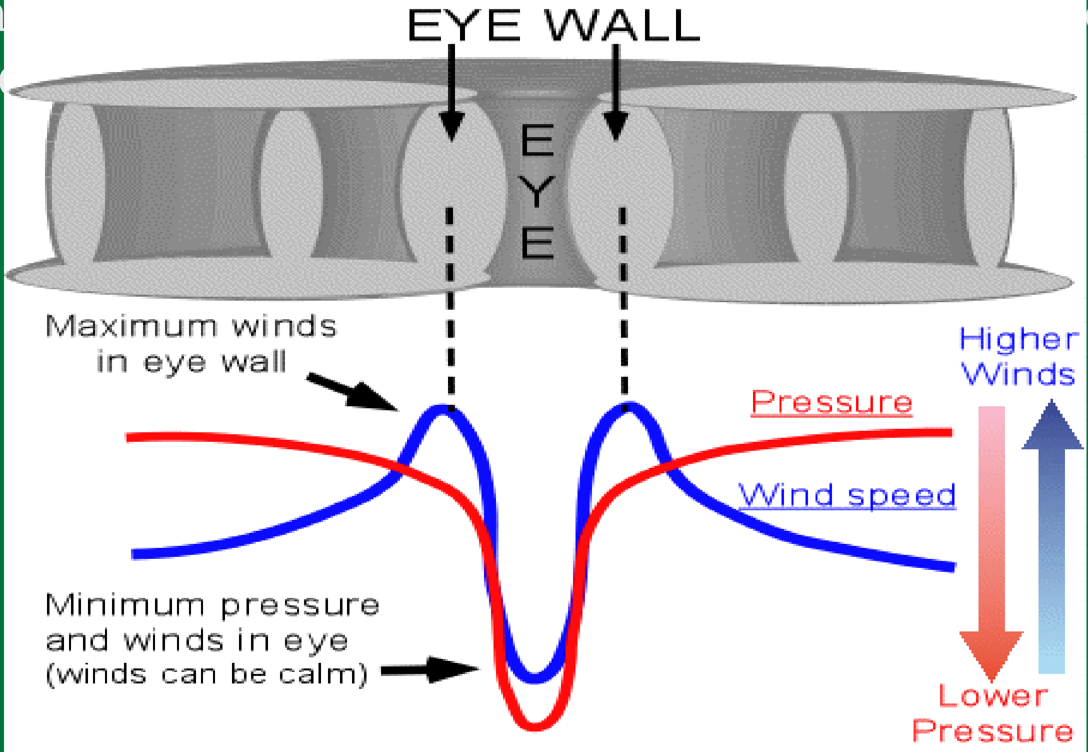


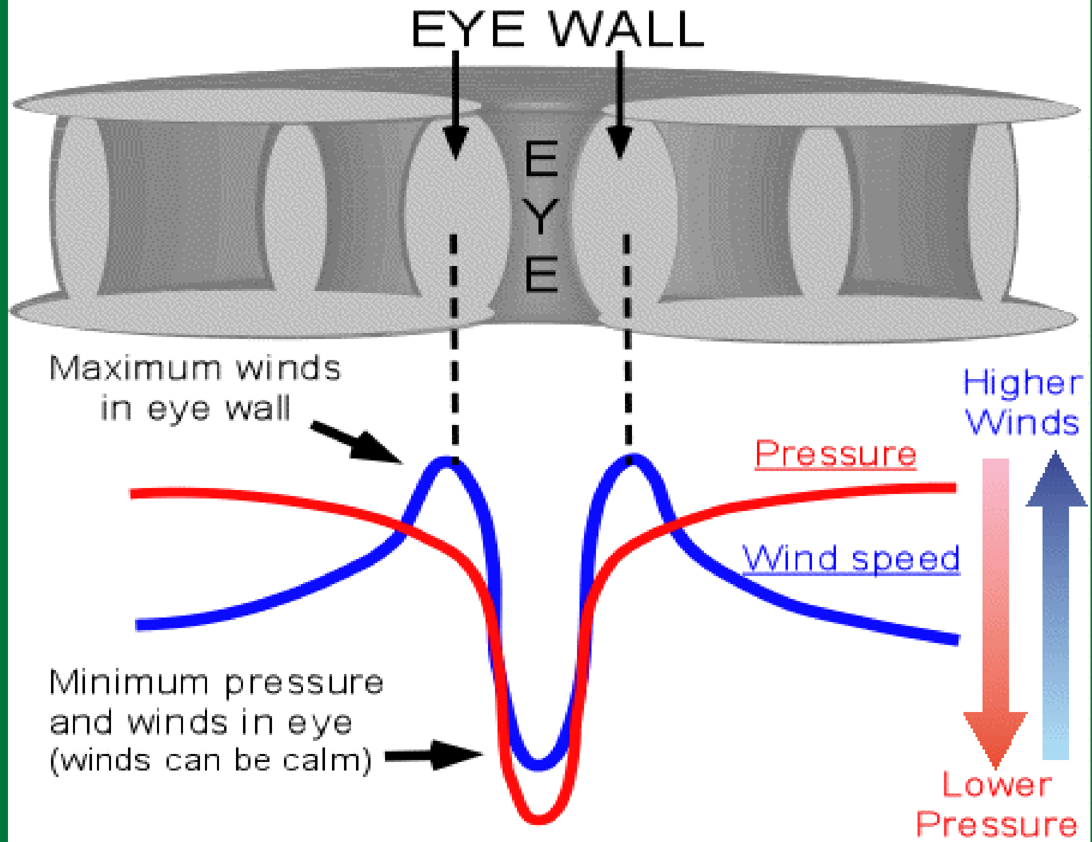
A schematic of this banding feature can be seen in the diagram above. The thunderstorms are now organized into regions of rising and sinking air. Most of the air is rising, but there is a small amount found in between the thunderstorms that is sinking.

Pressure and Winds

the distribution across a hurricane

Atmospheric pressure and wind speed change across the diameter of a hurricane. To demonstrate, the diagram below shows a rough profile of wind speed (blue) and surface pressure (red) across a hurricane. Between 100-200 kilometers from the eye, the winds are fast enough to qualify as tropical storm force. The atmospheric pressure here will still be relatively high compared to the storm's center at about 9901010 millibars. However, the pressure gradually falls and the wind speed rises upon getting closer to the eye wall. It is only over the la ges in pressure and win





The pressure begins to fall more rapidly while the wind speed simultaneously increases. Within the eye wall, the wind speed reaches its maximum but within the eye, the winds become very light sometimes even calm. The surface pressure continues to drop through the eye wall and into the center of the eye, where the lowest pressure is found. Upon exiting the eye, the wind speed and pressure both increase rapidly. The wind speed again reaches a maximum in the opposite eye wall, and then quickly begins to decrease. The wind and pressure profiles inside a hurricane are

Movement of Hurricanes

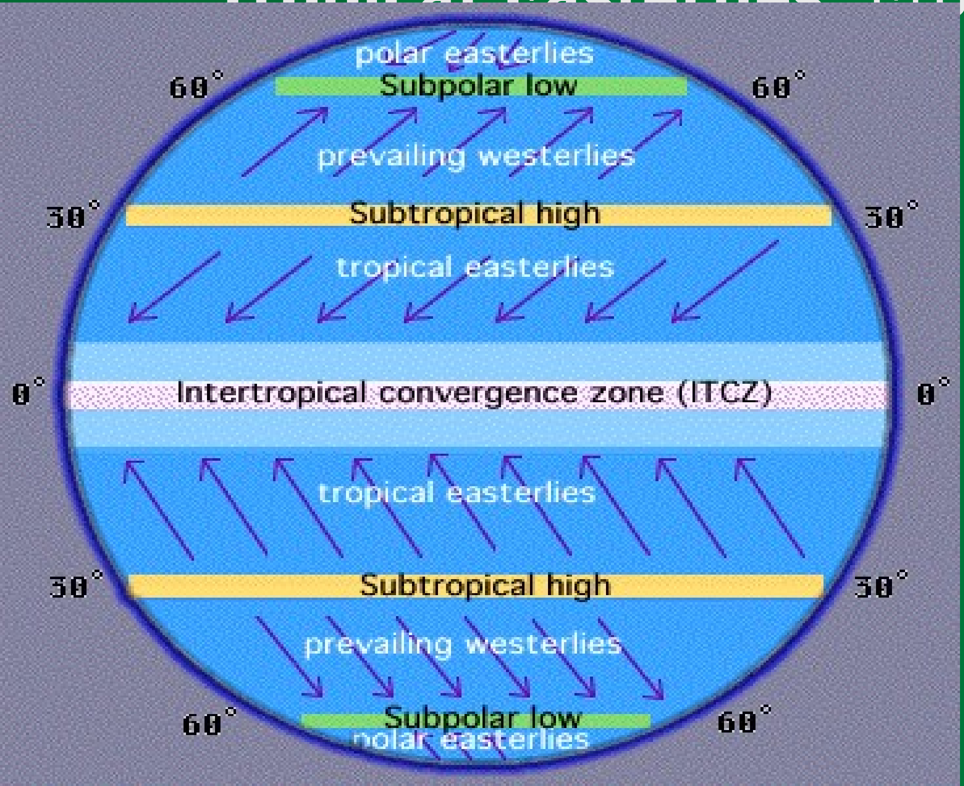
steered by the global winds

The global wind pattern is also known as the "general circulation" and the surface winds of each hemisphere are divided into three wind belts:

Polar Easterlies: From 60-90 degrees latitude.

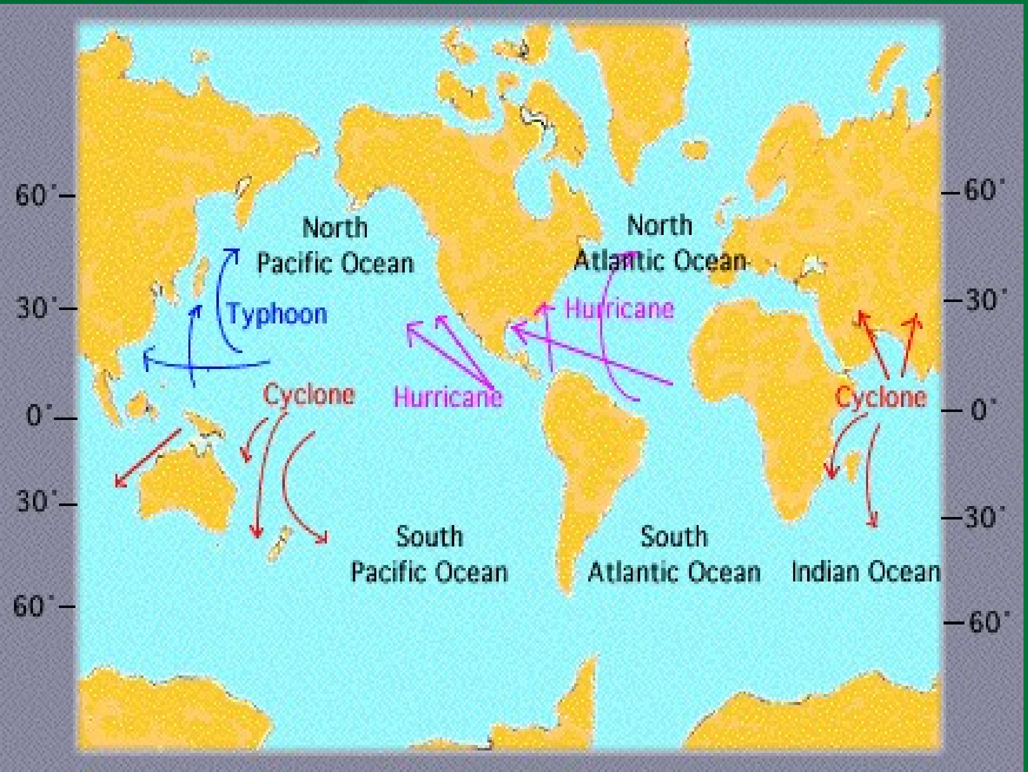
Prevailing Westerlies: From 30-60 degrees latitude (aka Westerlies).

Tropical Easterlies: From 0-30 degrees latitude (aka



The easterly trade winds of both hemispheres converge at an area near the equator called the "Intertropical Convergence Zone (ITCZ)", producing a narrow band of clouds and thunderstorms that encircle portions of the globe.

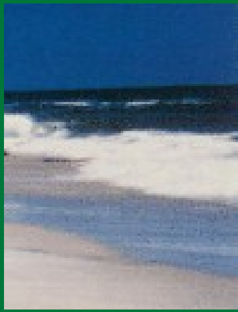
The path of a hurricane greatly depends upon the wind belt in which it is located. A hurricane originating in the eastern tropical Atlantic, for example, is driven westward by easterly trade winds in the tropics. Eventually, these storms turn northwestward around the subtropical high and migrate into higher latitudes. As a result, the Gulf of Mexico and East Coast of the United States are at risk to experience one or more hurricanes each year.



In time, hurricanes move into the middle latitudes and are driven northeastward by the westerlies, occasionally merging with midlatitude frontal systems. Hurricanes draw their energy from the warm surface water of the tropics, which explains why hurricanes dissipate rapidly once they move over cold

Damage caused by hurricanes

With hurricanes being as powerful as they are, it is not surprising that upon landfall they cause damage and destruction. Even when the hurricane has yet to make landfall, its effects can be dangerous. However, most of the damage caused to man and nature occur as a hurricane makes landfall.



Each of the above phenomena can turn a hurricane into a home-wrecker, a nature-destroyer, and even a killer. Some tropical storms that make landfall cause damage in these ways, but very rarely do they do so in as significant a manner as do hurricanes.

Strong Winds

determines the intensity of a hurricane

Strong winds are the most common means of destruction associated with hurricanes. Their sometimes continuous barrage can uproot trees, knock over buildings and homes, fling potentially deadly debris around, sink or ground boats, and flip cars.

The intensity of a tropical cyclone is measured by the highest sustained wind speed found within it. Once it becomes a hurricane, the relative strength of that hurricane is also measured on a scale based on its greatest wind speed. This scale is named the Saffir-Simpson scale for the men who invented it. The scale is listed below.

Scale Number Category	**Central Pressure** mb inches	**Wind Speeds** mi/hr knots	**Storm Surge** feet meters	**Observed Damage**
1	>=980 >=28.94	74-95 64-82	4-5 ~1.5	some damage to trees, shrubbery, and unanchored mobile homes
2	965-979 28.50-28.91	96-110 83-95	6-8 ~2.0-2.5	major damage to mobile homes; damage buildings' roofs, and blow trees down
3	945-964 27.91-28.47	111-130 96-113	9-12 ~2.5-4.0	destroy mobile homes; blow down large trees; damage small buildings
4	920-944 27.17-27.88	131-155 114-135	13-18 ~4.0-5.5	completely destroy mobile homes; lower floors of structures near shore are susceptible to flooding
5	<"920" <"27.17"	>"155" >"135"	>"18" >"5.5"	extensive damage to homes and industrial buildings; blow away small buildings; lower floors of structures within 500 meters of shore and less than 4.5 m (15 ft) above sea level are damaged

The Saffir-Simpson scale categorizes hurricanes on a scale from 1 to 5. Category 1 hurricanes are the weakest, and 5's the most intense. Hurricanes strong enough to be considered intense start at category 3 or with sustained winds exceeding 96 knots (111 mph). For reference, there have only been two category 5 hurricanes that made landfall on the mainland U.S. (Florida Keys 1935 and Camille 1969). Recent intense hurricanes to make landfall on the United States were Opal in 1995 and Fran in 1996.

Saffir-Simpson Hurricane Damage-Potential Scale

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Storm Surge

a concern to coastal residents

One major cause of hurricane damage is storm surge. Storm surge is the rising of the sea level due to the low pressure, high winds, and high waves associated with a hurricane as it makes landfall. The storm surge can cause significant flooding and cost people their lives if they're caught unexpected.

Storm surge can be understood by looking at the video below. The strong winds blowing towards the shore help push water towards shore on the right side of the hurricane's direction of motion. This piling up contributes to most of the coastal flooding.

Also, the central pressure of a hurricane is so low that the relative lack of atmospheric weight above the eye and eye wall causes a bulge in the ocean surface level. This effect is similar to using a straw. When you use a straw, you decrease the air pressure in the straw, and the high pressure pushing down on the rest of the drink pushes the drink up the straw. Here it is the relative higher pressure on the ocean around the outside the hurricane that

Ocean waves also contribute to the overall storm surge as the waves which may only be a couple of meters out at sea grow as the ocean depth decreases to several meters at the shore. The photograph below is of the exact same area as the photograph above, but after the storm surge has caused extensive damage.

Typical storm surge heights vary with the hurricane's intensity, but they can range from only 1 to more than 5 meters (3 to 25+ feet). The inland penetration of the storm surge's damage can vary depending on the topography. In some locations, like Florida, the landscape is quite flat and if the ocean is raised a couple of meters, the intrusion of the storm surge can be as far as a mile or two. Storm surge creates steady flooding, and can wreck homes and pull boats and cars inland or out to sea.

Heavy rain and Flooding

a problem of any tropical disturbance

Apart from the storm surge, heavy rainfall causes both flash and long term flooding. Tropical storms and hurricanes are known to dump as much as a meter (about 3 feet) of rain in just a couple of days, creating big problems for residents who believe they are safe just because they do not live on or near the coast. In fact flooding kills more people than the strong winds do. Here are some of the rainfall totals which occurred in October of 1 landfall of Hurricane Opal.

After a hurricane has come inland, it does begin to deteriorate. However, it still produces a lot of rainfall. Even when a tropical system is as weak as a depression, it is still a very strong storm when compared to average

Tornadoes

even in hurricanes

With technology in its current state, forecasters can give residents in the path of hurricanes advanced warnings to help prevent casualties due to storm surge, strong winds, and heavy rain, -- each of which claimed many lives during the first half of the century. Now, more people are caught off guard by the tornadoe

r to

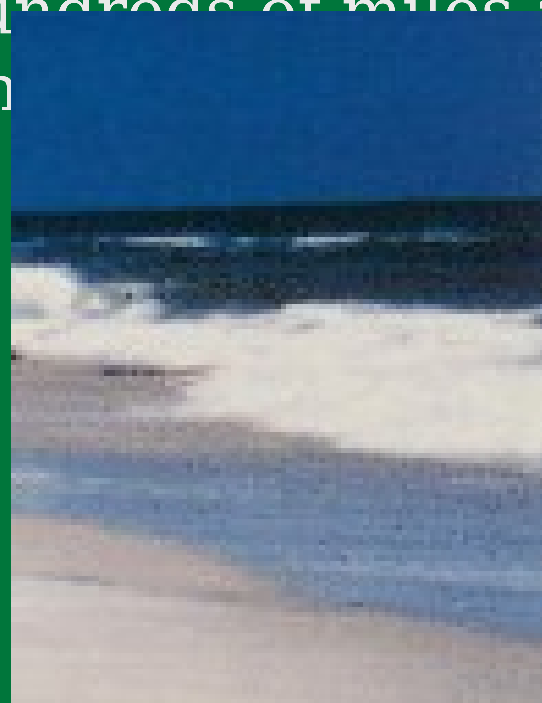
that seen

These tornadoes are also found close to or within the eye wall. Often these tornadoes occur in heavy rain storms, making them difficult, if not impossible, to see. Advances in radar technology have given the public more lead time than before, but these twisters are still very dangerous and can cause quite a bit of

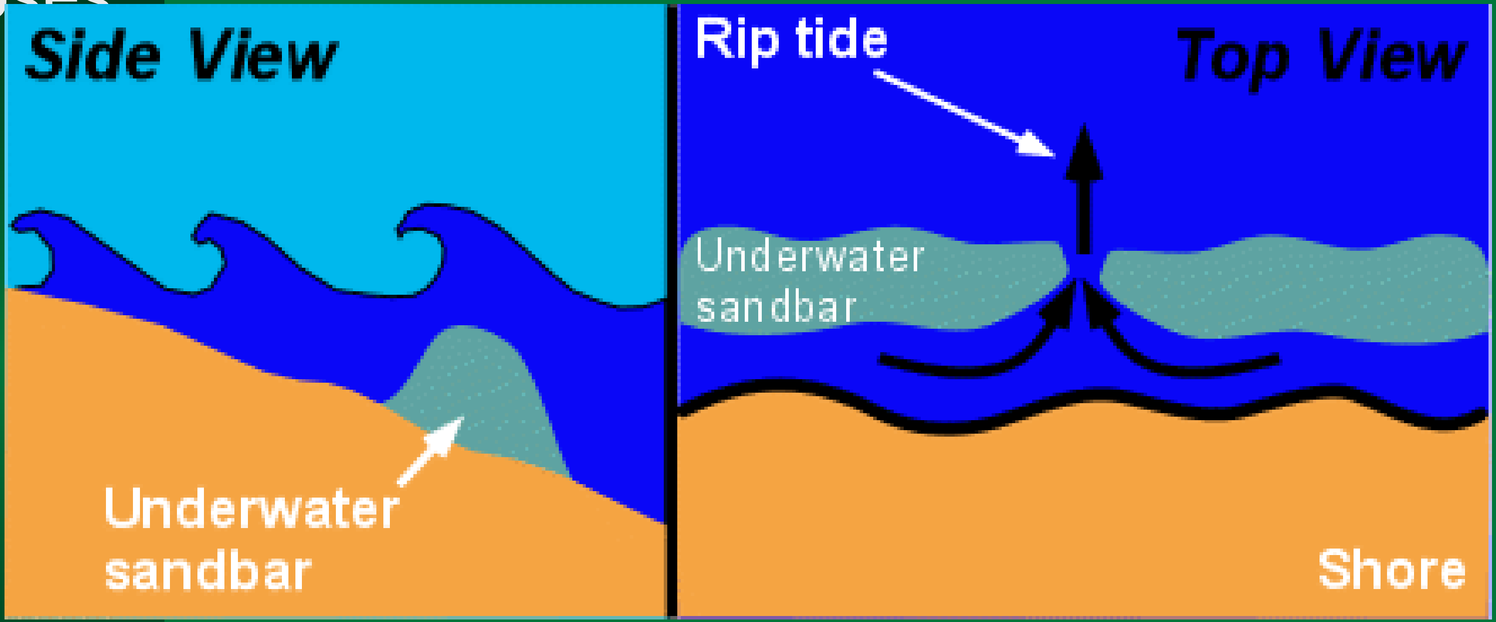
Rip Tides

a danger to swimmers

Another almost overlooked aspect of hurricanes and tropical storms are rip tides (or rip currents). Rip tides are strong sea currents which push away from the shore as a strong storm is near. They are formed by the strong winds pushing water towards the shore. Tropical cyclones' winds push waves up against the shoreline even if they are hundreds of miles away, so rip tide warnings are often ion of a nearby hurricane.



As seen in the side view diagram below, the incoming waves create an underwater sandbar close to shore, and the waves push more and more water in between the sandbar and the shore until a section of this sandbar collapses.

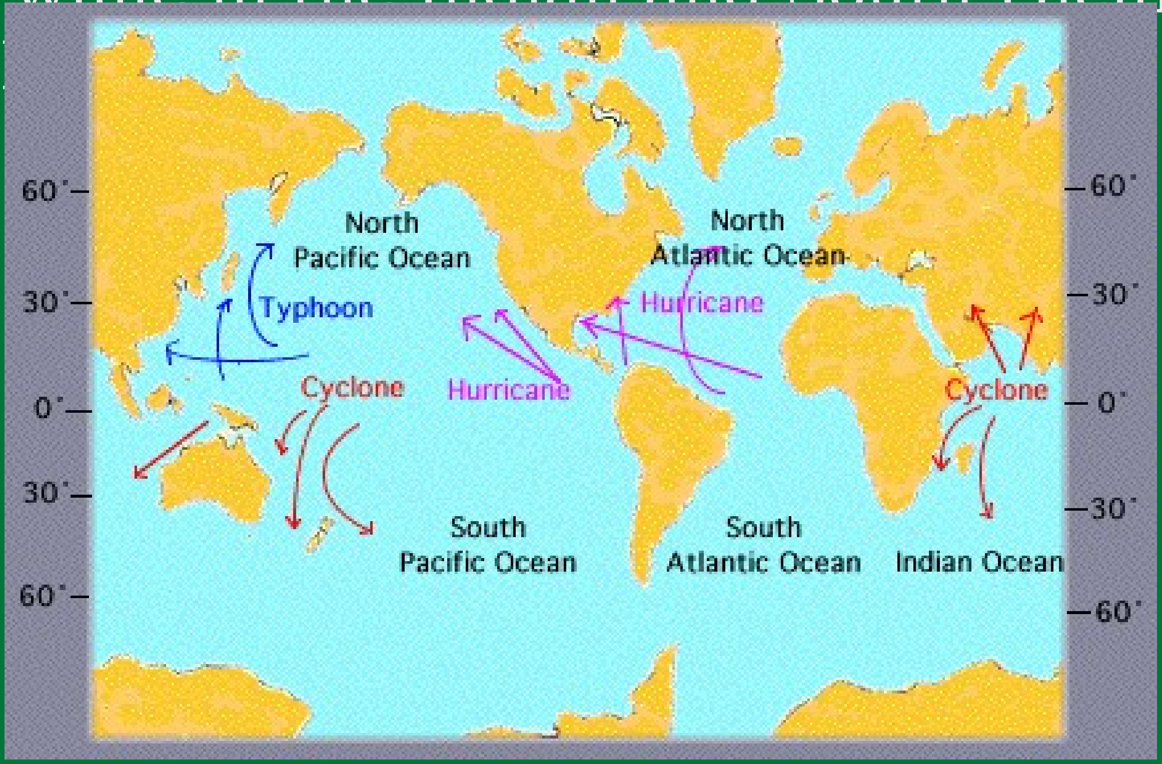


All the excess water is forced through this gap, creating an extremely strong but narrow current away from the shore (seen in top view diagram above). In fact, rip tides are so strong that trying to swim back to shore against the rip tide current will only tire you out and make it that much more difficult for you to survive. Rip tides are narrow enough that if

How They Are Named

differently in different parts of the world

Hurricane-like storms are called by different names in the different regions of the world. For example, the name "hurricane" is given to systems that develop over the Atlantic or the eastern Pacific Oceans. In the western North Pacific and Philippines, these systems are called "typhoons" while in the Indian and South Pacific Ocean, they are ca

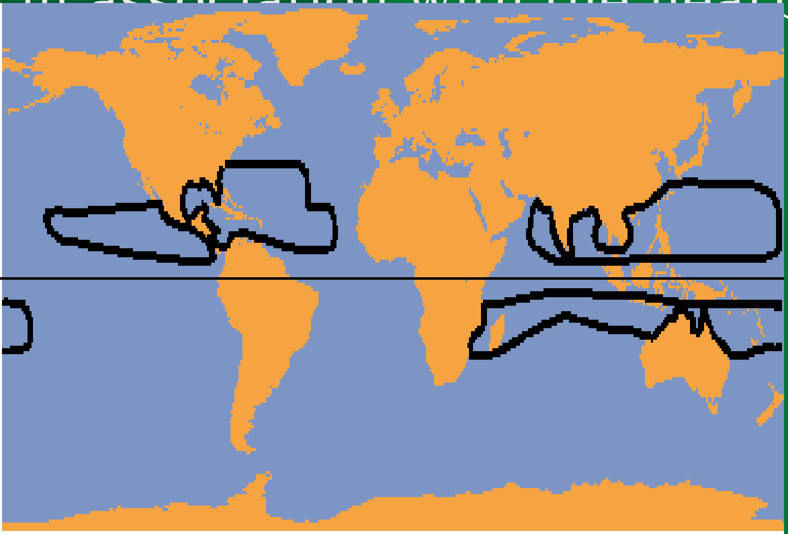


Global Activity

tropical cyclones around the world

Even though Atlantic Ocean hurricanes receive a lot of attention, only 12% of tropical cyclones seen world-wide are located here. These dangerous storms can be found in three of our four oceans, and in both hemispheres. The diagram below shows the regions of the Earth where tropical storms originate.

Approximately 96 tropical cyclones are reported annually. The Western North Pacific Ocean averages more than 25 hurricanes (called typhoons) each year. Another location with great activity is the Indian Ocean. No other part of the world has so much activity in such a small area. This is because of the thunderstorms that develop in association with the nearby ITCZ and the very warm Indian

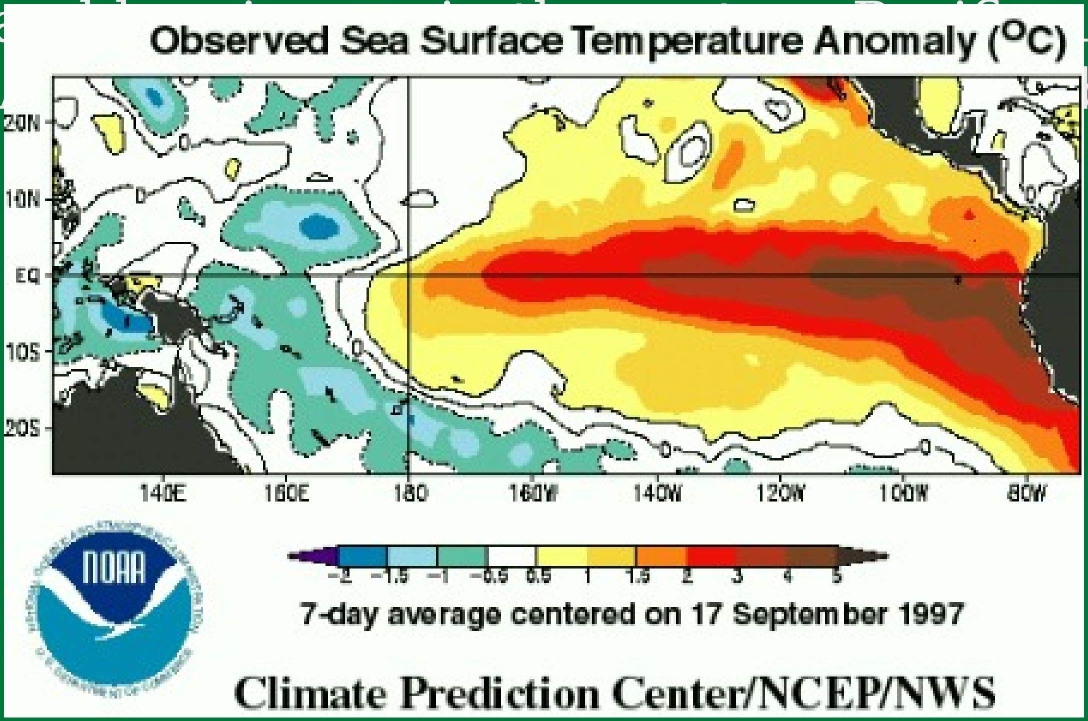


The Southern Hemisphere also experiences tropical cyclones. However, they are confined to the Western Pacific and Indian Oceans. Even though ocean temperatures are warm enough, a small region without tropical cyclones exists near the equator. This is because for all the

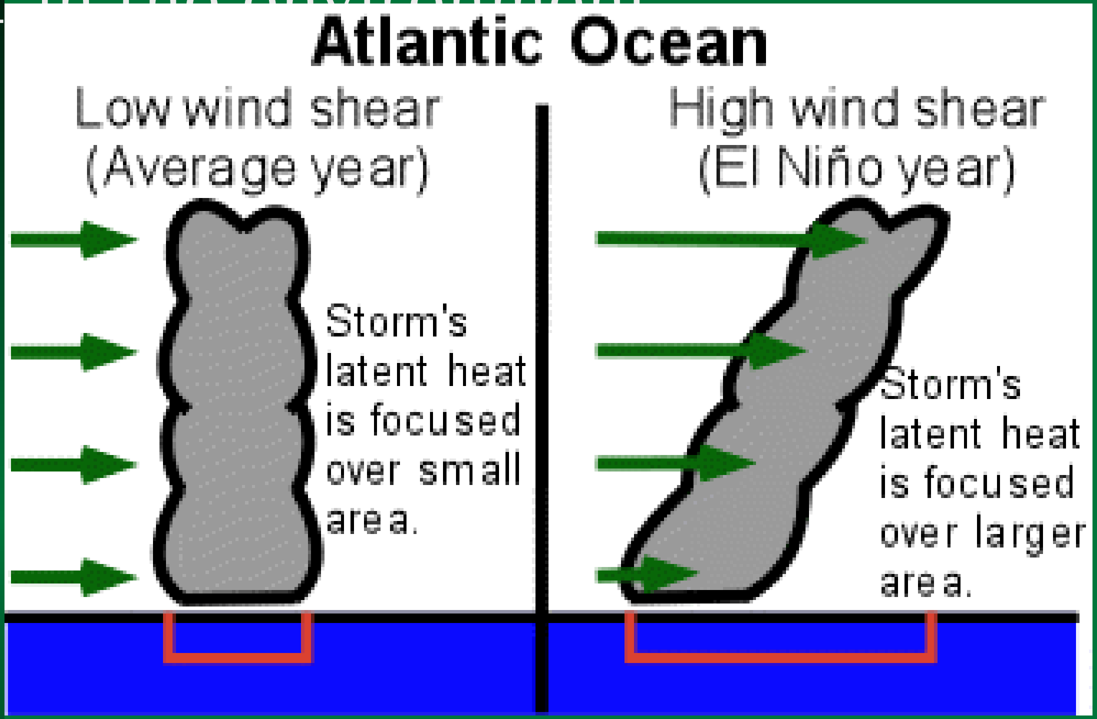
Interaction with El Niño

how hurricane frequency may be affected

Researchers continue to investigate possible interactions between hurricane frequency and El Niño. El Niño is a phenomenon where ocean surface temperatures become warmer than normal in the equatorial Pacific. (The chart below shows the anomaly associated with the most recent El Niño in 1997-1998.) In general, warm El Niño events are characterized by more tropical storms a … nd a decrease in the A … bean Sea.



The primary explanation for the decline in hurricane frequency during El Niño years is due to the increased wind shear in the environment.



In El Niño years, the wind patterns are aligned in such a way that the vertical wind shear is increased over the Caribbean and Atlantic. The increased wind shear helps to prevent tropical disturbances from developing into hurricanes. In the eastern Pacific, the wind patterns are altered in such a way to reduce the wind shear in the